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ARMSTRONG LABORATORY

USING COMPUTERIZED NEUROPSYCHOLOGICAL TESTING TO ASSESS AVIATOR SKILLS

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The Office of Public Affairs has reviewed this technical report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*

Successful pilots must be cognitively and psychologically "fit" to preserve cockpit situational awareness while executing complex job demands in an unforgiving environment. The neuropsychological attributes of successful U.S. Air Force (USAF) aircrew, however, are largely unstudied. To conveniently collect a large sample of aviators' data for comparison to mission performance, an easy-to-use and reliable test delivery system is required. The Neuropsychiatrically Enhanced Flight Screening (N-EFS) program is one product of an effort by Armstrong Laboratory's (AL) Neuropsychiatry Branch (AOCN). N-EFS measures the cognitive functioning (using the Multidimensional Aptitude Battery, MAB; and CogScreen) and psychological attributes and crew resource management potential (using the Personal Characteristics Inventory, PCI; and the Revised NEO-Personality Inventory, NEO-PI-R) of all USAF pilot candidates. This data will establish a range of cognitive attributes of pilot applicants, and will provide MAB and CogScreen baseline data for future reference. The N-EFS program also seeks to validate the MAB, CogScreen, NEO-PI-R, and PCI as future tools for pilot selection and understanding situational awareness. N-EFS builds on earlier AL/AOCN efforts to develop a "field-friendly," self-administered, computerized psychometric testing battery to define attributes of successful pilots.

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Contents

List of Tables

USING COMPUTERIZED NEUROPSYCHOLOGICAL TESTING TO ASSESS AVIATOR SKILLS

Neuropsychological (cognitive and personality) data on successful U.S. Air Force (USAF) aviators remains scarce, primarily due to limited access to aircrew (13). As military forces decrease while mission demands increase and diversify, selecting pilots for stress resilience, situational awareness (SA), and good long-term mental health becomes more important. The Armstrong Laboratory (AL) Neuropsychiatry Branch (AOCN) began research and development (R&D) of a microcomputer-delivered psychometric test battery in 1991 (12). The goal was to produce a tool that would be standardized in test delivery and reliable in data collection. Lessons learned from early deployment of the test battery led to changes in test battery length, psychometric tests utilized, and method of access to participating aviators. One product from this AOCN R&D effort is the USAF psychological assessment battery administered to all pilot candidates at the time of flight screening, termed the Neuropsychiatrically Enhanced Flight Screening (N-EFS) program.

Testing of attitude, intelligence, and cognitive functioning has not formerly been accomplished on candidates for undergraduate pilot training (UPT). The contribution of personality and attitude to pilot success is poorly defined, while sensory-motor skills have been more frequently scrutinized (5, 6, 23). Furthermore, previous selection studies (4, 27, 28, 31) used the criterion of success as completion of UPT, rather than actual mission-ready status. Using this short-term criterion plagues research results with the "honey-moon effect," where pilot students attempt to look their best by sustaining a high level of performance, but only in the short-run (17). Measures that focus on who *can* (aptitude) finish pilot training misses information on who *will* (motivation) finish pilot training and evolve into effective military resources.

Beyond student pilot data, mission-ready military pilot psychometric norms are severely limited or based on very small, specialized populations (3, 11, 13, 26, 34). These previous collections of psychometric norms have gravitated toward astronauts, fighter and test pilots, to the exclusion of tanker, transport, and bomber aviators. Representative data on female military aviators is even more scarce, to the point of being completely nonexistent. Understanding the unique stressors that females aviators face in their flying careers, however, will be imperative as they comprise growing numbers among aircrew.

Demands for greater aircraft speed have challenged airframes; now speed of information processing is becoming a critical skill for the new generation of military pilot. The successful aviator must choose the most critical data to maintain flight safety and achieve mission completion, from a myriad of cockpit instruments (16). How aviators optimally process this information is becoming an important operation to define. This "extraordinary awareness of the total flight environment" (32) is one definition of situational awareness (SA).

Exactly what SA is, how one is to measure it, and whether it is an inherent trait or a trainable skill are open questions. Some common components in varying definitions of SA are as follows: the capability to compose a multitude of data bits into a composite understanding (10), to relate this understanding to skilled knowledge of aircraft and environment (20), to anticipate future actions by matching this information to known patterns (16) and subsequently to prioritize one's own actions to maximize inherent advantages. Stress tolerance and emotional control (psychological fitness) would appear to be critical factors associated with SA, and considerable effort is being dedicated by AL to develop tools to measure this combination of variables.

N-EFS will utilize neuropsychological testing to assess human factors necessary for successful upgrade to a weapon-system qualified USAF pilot. Poor psychological fitness may negatively impact flight safety and mission completion (2, 33). For these reasons, N-EFS information may later have predictive value for cockpit mastery, after comparing data from successful versus unsuccessful aspiring mission-ready pilots. Beyond these research functions, N-EFS will also record an individual's cognitive baseline should future comparison be needed, e.g., after an adverse neurological event.

Computerized psychometric testing is a key component to the convenient assessment of multiple participants at multiple test sites. Deploying a computerized battery offers greater access to successful aviators, since testing can go to their location using a standardized delivery system with reliable data collection. Fewer manhours are required in data downloading and test scoring when using a computerized method. Finally, there is evidence to suggest that volunteers will be more likely to offer information and complete testing when it is offered on computer (24, 30).

The Test Battery

The tests chosen for the AL/AOCN battery will measure a student pilot's psychological and cognitive functioning. Cognitive assessment will be measured using the Multidimensional Aptitude Battery (MAB, 21) and CogScreen (18). The MAB is an IQ test developed by Douglas N. Jackson, Ph.D. that has a high correlation (.94-.98) with the Wechsler Adult Intelligence Scale-Revised (WAIS-R, 7). Glimpses of the USAF aviator population have suggested that they tend to have superior IQ (11, 13). Aviators with good situational awareness, however, may have special gifts in certain areas of measured intelligence, such as spatial skills or rapid information processing abilities (9, 32). Administered in ten seven-minute blocks by computer, the MAB combines subtest scores into verbal, performance, and full scale IQs. These subtests may correlate with cockpit performance.

Table 1

Multidimensional Aptitude Battery (MAB)

	Subtests
Verbal IQ	*Information* *Comprehension* *Arithmetic* *Similarities* *Vocabulary*
Performance IQ	*Digit Symbol* *Picture Completion* *Spatial* *Picture Arrangement* *Object Assembly*
Full Scale IQ	Comprised of all subtests

The CogScreen is a self-administered neuropsychological screening tool, which requires a light-pen and a video graphics capable (VGA) computer monitor. Testing has begun with commercial aviator populations using the CogScreen to assess learning and retention abilities, and is now correlating these factors with cockpit performance (19). In comparison to traditional neuropsychological assessment, which is administrator labor-intensive and time-consuming, CogScreen may ultimately prove superior in identifying cognitive subtleties that are key to situational awareness in a high-demand environment. The CogScreen may be administered individually or in a group setting.

Table 2

CogScreen

Name of Test	What it Measures
Backward Digit Span	Attention, working memory, verbo-sequential processing
Math Problems	Working memory, long-term memory, mental arithmetic, logical reasoning
Visual Sequence Comparison	Attention, working memory, and verbo-sequential processing
Symbol Digit Coding	Attention, visual scanning, working memory, verbo-sequential processing
Symbol Digit Coding - Immediate Recall	Immediate recall
Matching to Sample	Visuo-spatial memory, response speed
Manikin Figures	Visuo-spatial orientation, ability to rotate mental images, long-term memory
Divided Attention Test	Speed and accuracy of responding. In dual task mode: Divided attention, working memory, visual-spatial processing, verbo-sequential processing
Auditory Sequence Comparison	Attention, working memory, verbo-sequential processing
Pathfinder	Verbo-sequential processing, working memory, attention, ability to systematically apply rules
Symbol Digit Coding - Delayed Recall	Memory and recall
Shifting Attention Test	Concept formation, conceptual flexibility, deductive reasoning, response interference

(Extracted from the unpublished CogScreen User's Manual, authored by Richard L. Horst and Gary G. Kay, Ph.D., Georgetown University School of Medicine, Washington, DC, December 4, 1991.)

Human factors data on personality and judgment will be measured by the Personal Characteristics Inventory (PCI, 6) and the Revised NEO Personality Inventory (NEO-PI-R, 8). The PCI has been used by commercial airlines as a tool to measure judgement and potential for effective crew resource management (15). It consists of 254 questions with a Likert response scale. Aircrew responses are categorized into eight groups ranging from "right stuff" to "wrong stuff" in cockpit crew coordination. Already widely used in civilian aerospace operations, groups generated by the PCI can now be correlated more specifically to military aviation skills and success.

Table 3

Personal Characteristics Inventory (PCI)

Instrumentality (Goal Orientation)	*Mastery*
	Work
	Competitiveness
	Instrumentality (I+)
	Negative Instrumentality (I-)
Expressivity (Interpersonal Orientation)	*Expressivity (E+)*
	Verbal Aggressiveness (Eva-)

(The following scales can also be gleaned: *Negative Communion* [*Ec*-], *Achievement*, and *Impatience* including *Achievement Striving* [*AS*] and *Impatience/Irritability* [*I/I*; 6].)

Consisting of 240 questions with a Likert scale response format, the NEO-PI-R is a gauge of normal personality functioning based on the five-factor model (8, 14). Key facets measured are depicted in Table 4. In the N-EFS test battery, the NEO-PI-R is not being used to identify abnormal personality (a *screen-out* function). Previously studied aviators and student aviators, as a group, appear to harbor very little personality pathology (1, 22, 29). Rather, the NEO-PI-R may identify whether some personality traits are more predictive of success in military aviation, which would aid future pilot selection (*screen-in*, 25).

Table 4

Revised NEO Personality Inventory (NEO-PI-R)

Domain	Facet
Neuroticism (N)	*Anxiety (N1)* *Angry Hostility (N2)* *Depression (N3)* *Self-Consciousness (N4)* *Impulsiveness (N5)* *Vulnerability (N6)*
Extraversion (E)	*Warmth (E1)* *Gregariousness (E2)* *Assertiveness (E3)* *Activity (E4)* *Excitement-Seeking (E5)* *Positive Emotions (E6)*
Openness (O)	*Fantasy (O1)* *Aesthetics (O2)* *Feelings (O3)* *Actions (O4)* *Ideas (O5)* *Values (O6)*
Agreeableness (A)	*Trust (A1)* *Straightforwardness (A2)* *Altruism (A3)* *Compliance (A4)* *Modesty (A5)* *Tender-Mindedness (A6)*
Conscientiousness (C)	*Competence (C1)* *Order (C2)* *Dutifulness (C3)* *Achievement Striving (C4)* *Self-Discipline (C5)* *Deliberation (C6)*

Method

The AL/AOCN computerized test battery can run under MicroSoft Windows 3.1$_{TM}$ or MicroSoft Disk Operating System (MS-DOS)® version 5.0 (or higher). The computer processing units (CPU) must have an Intel 80386 or higher processor with at least 4 MB RAM, running at 25 Mhz or greater and 10 MB of hard

disk storage space. Either notebook or desktop CPU with VGA cathode-ray tube (CRT) are required to administer the entire test battery. Although the MAB, PCI, and NEO-PI-R can be successfully completed on the LCD notebook computer screens, CogScreen administration requires a CRT for its light pen and light-pen interface hardware and software.

A participant's test data is captured on either 3.5 inch or 5.25 inch floppy disk medium. Floppy disks are preformatted with directories to which test specific data are guided for storage. The absence of these directories stops the battery from proceeding, and this disk preformatting functions as one of the battery's security measures. Test scoring is completed separately from test administration, and is facilitated by the partitioning of specific test responses into the separate directories. Scaled scores are written to both the individual's scoring disk and later to a central AL/AOCN database for security and further analysis. Database security design permits access only to specific investigator-users.

N-EFS testing screens pilot candidates at Hondo, Texas, and the Air Force Academy (USAFA) in Colorado Springs, Colorado, before they enter UPT. Their commissioning source is either Reserve Officer Training Corps (ROTC), the USAFA, Officer Training School (OTS), or the Air National Guard (ANG). All (male and female) candidates are in their early 20's. OTS-commissioned officers have, at minimum, a college education. ROTC and USAFA cadets will be entering, or are active in, their senior scholastic year.

All pilot candidates are required to complete the MAB and CogScreen to record entry-level data at the commencement of flight screening at Hondo or USAFA. All students' medical records are annotated to indicate that N-EFS testing has been accomplished, but specific results are not entered in the medical record (Appendix A). Individual IQ scores are not revealed to any participant, or any other unauthorized individual, as a part of this study. Data is stored at AL/AOCN for future medical reference, to be released on an "as-needed" basis.

All flight screening candidates are invited to participate in the research portion of the program. All applicants are thoroughly briefed on the nature of the study, both verbally by a licensed psychologist and in writing, as reflected by the informed consent document (Appendix B). Questions about the study are actively solicited and answered by the psychologist (Appendix C). Volunteer participants then complete the NEO-PI-R, PCI, MAB and CogScreen and agree to allow their results to be analyzed against future occupational success. If an individual does not consent to the research portion of the study, then MAB and CogScreen results are withheld from the selection-tool validation study; the NEO-PI-R and PCI are not administered.

All tests are presented to participants on computer for ease of administration and standardization of stimulus conditions. An experienced mental health technician oversees all data gathering. Participants are advised that follow-on studies will be initiated two years into their particular airframe assignment, to correlate their data with their eventual weapon-system performance (the outcome criterion). As initial data will be calculated into standard (normalized) scores, parametric inferential statistics will be applied.

Discussion

The smaller USAF aviator force of the future will rely increasingly on the accuracy and skill of fewer aviators flying fewer, but more sophisticated and demanding aircraft. Defining the neuropsychological characteristics of successful aircrew could yield greater understanding of human factors and the elements of situational awareness. This research has not been accomplished to date because it is difficult to obtain such

information from aircrew, as they fear test results may lead to medical disqualification. This data could improve personnel selection, facilitate medical waiver, enhance crew resource management, and educate scientists who develop USAF selection and training programs. In addition, this knowledge could improve flight surgeons' abilities to support the psychological health of aircrew.

Computerized, self-administered psychometric testing has been the focus of AL/AOCN research and development because it offers a method to gather important data. N-EFS will identify the psychological attributes of aviation candidates, and may help discriminate candidates who ultimately prove successful from unsuccessful candidates. Results of the research portion of N-EFS could help identify neuropsychological characteristics of those candidates who will most likely become mission-qualified USAF pilots. This effort will require several additional years of follow-up but conclusions would not be based on aviator performance within the confounds of the "honeymoon effect." Data from the MAB, CogScreen, PCI and NEO-PI-R will offer a balanced perspective on the human factors of the modern USAF aviator, and shed light on cognitive aspects of situational awareness.

Vidulich has suggested that SA is a combination of perceptual motor skills and cognitive skills (32). SA requires the capability to sort through layers of information in a time-critical period and then effectively prioritize task completion. In addition, he notes that attentional capabilities, personality reactions to stress, and emotional control have a critical impact on SA. Personality traits and cognitive capabilities can be studied through the N-EFS program. Comparing results of successful pilots (those who successfully upgrade to full mission-ready status) to unsuccessful (those who fail to upgrade) could identify areas of cognitive performance important in SA.

Placing a notebook computer in the flight surgeon's office might be the next step to gain access to pilot volunteers who will anonymously take neuropsychological tests. If offered during their routine flying physical visit to the flight surgeon's office, this method could be an unobtrusive way to gain insight into the skills of mission-qualified aviators. Current aviator occupational norms for these instruments could be defined, as they currently do not exist. What remains to be demonstrated is the reliability and validity of computerized neuropsychological testing in the field, or in the flight surgeon's office. With greater use, the development of greater security measures to safeguard the test battery will be needed, as well. The responses could be captured at the source, downloaded to AL/AOCN via modem, scored, and archived with summary information and interpretation reported back to the referring flight surgeon's office.

Support must continue from both volunteer aviator participants and visionary USAF managers to maintain these computerized testing programs through their formative early phase. In a time of downsizing, it would be easy to cut a new program "to save time and money." This program, however, may lead to the optimization of aircrew selection and retention, leading to increased force effectiveness. With fewer aviators shouldering greater responsibility for USAF mission completion, proceeding into the 21st century of military aviation operations without a clear understanding of aviator human factors may ultimately be "penny-wise but pound foolish."

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Appendix A

(Medical Record Entry Form)

ENHANCED FLIGHT SCREENING - MEDICAL

S: Student aviator routinely administered the Multidimensional Aptitude Battery (MAB) and CogScreen. This testing is for future baseline functioning comparison only.

O: Student complied and completed testing.

A: Deferred.

P: Student not offered individual feedback on results. Information on results of the above testing is available to duly credentialed providers by contacting AL/AOCN @ DSN 240-3537, Commercial (210) 536-3537.

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Appendix B

(Informed Consent Document)

Informed Consent Document

Neuropsychiatrically Enhanced Flight Screening (N-EFS)

1. I understand that I am invited to participate in taking a set (battery) of psychological tests and questionnaires administered by the Neuropsychiatry Branch, Clinical Sciences Division, Armstrong Laboratory. This testing will be approximately four (4) hours long. This testing will not affect my status in the EFS program or follow-on undergraduate pilot training (UPT) or future assignments. The purpose is to determine if testing can predict who will complete UPT, and whether testing can be used (in the future) to help select which pilots are best suited for particular airframes. I understand that the data I supply will be entered into a database for group statistical analysis. While this testing is primarily for research purposes, I am aware that this material will be kept on file and may be used to compare to my subsequent test performance in the event that I need to be considered for a medical waiver to continue, or return to, flying status. It is possible that such a comparison may negatively or positively influence my chances of being granted a medical waiver to return to flying status. My participation in this study is completely voluntary and nonparticipation will not negatively impact my status as a candidate for pilot training. Individuals in a position to decide my future as an Air Force student pilot will NOT be notified if I decline to participate. I understand that the researchers will safeguard my responses to the very best of their ability but that they cannot guarantee that this information will not be requested by any of my future commanders. In other words, I understand that "patient/doctor privilege" does not exist in any form in the military, including my participation in this study. My testing results may be presented as part of an aggregate or summary in scientific publications or scientific presentations but will not be released in any fashion, except as described, that could be used to identify me without my future, expressed, written consent. This form does NOT constitute such consent. I understand that even if I decline to participate in the proposed research study, I will still be required to complete the CogScreen and the Multidimensional Aptitude Battery (MAB) for baseline functioning assessment purposes.

2. The tests are: the CogScreen, a measure of cognitive functioning; the Multidimensional Aptitude Battery (MAB), an intelligence test; the NEO Personality Inventory-Revised (NEO-PI-R), an inventory of normal personality functioning; and the Personal Characteristics Inventory (PCI), a tool to measure judgment and potential for aircrew co-ordination. The MAB and NEO-PI-R are commercially published tests while the PCI is a research instrument being developed to decrease human factors-related mishaps and increase aircrew effectiveness. The CogScreen was developed for use by the Federal Aviation Administration (FAA) to assess aviators after brain disease or injury. All tests are appropriate for administration to either males or females. I will complete the tasks with which I am presented to the very best of my ability. I will not remove any testing materials and will not advise future students of the contents of these tests.

3. There are no anticipated hazards or discomfort expected to result from this study. I understand that a licensed psychologist will be available during the testing procedure should I have any questions and that he/she will address my concerns without any prejudice toward me. If I have any questions or concerns after I complete this battery, I may call Capt (Dr) Ray King, aerospace clinical psychologist, at DSN 240-3537 or commercial: (210) 536-3537. I understand, however, that individual feedback on the results of my performance cannot be made available to me.

4. While I may not receive direct benefit from this study, my participation may help ensure the maintenance of a superior United States Air Force.

_____

Volunteer's Initials Date

5. There are no equivalent alternative procedures to procure the data sought by this research protocol.

6. Records of my participation in this study may only be disclosed in accordance to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations.

7. I understand that my entitlement to medical care or compensation in the event of injury are governed by federal laws and regulations, and if I desire further information I may contact the Brooks AFB Legal Office [DSN 240-3301, Commercial (210) 536-3301].

8. The decision to participate in this research is completely voluntary on my part. No one has coerced or intimidated me into participating in this program. I am participating because I want to. Capt (Dr) Ray King, aerospace clinical psychologist, or his designated licensed psychologist, has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that Capt King or his designate will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during the course of this research which may relate to my decision to continue participation, I will be informed. I further understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my entitlements. I also understand that the medical monitor of this study may terminate my participation in this study if he or she feels this may be in my best interest.

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Purpose is to request consent in approved medical research studies. The Air Force is attempting to learn the profile of the potentially successful military aviator, match abilities to specific types of airframes, and gather baseline information for possible future comparisons to aid medical evaluations when aviators need to be considered for waivers to return to flying status. The Social Security Number (SSN) is requested to help correctly identify and match data to the military member.

Routine Uses: None. Participation is voluntary. Information may be disclosed for any of the blanket routine uses published by the Air Force and reprinted in AFP 12-36 and in Federal Register 52 FR 16431. Failure to disclose information will not result in penalties. Individuals declining to participate will not be denied entry to undergraduate pilot training (UPT) or other training/assignment opportunities. Failure to participate may, however, result in delays in waiver consideration due to the lack of baseline information obtained before potential brain injuries. Declining participation will NOT, however, result in denial of future waiver consideration.

_____

Volunteer's Signature and Social Security Number Date

_____

RAYMOND E. KING, Capt, USAF, BSC Date
Aerospace Clinical Psychologist

_____

Witness (not directly involved) Date

Appendix C

(Questions posed by participants and answers they have received)

Pre-test

Q. Why can my Commander get the results of my testing but I can't? He could contact you with a cockamamie...

A. Commander has to have a need to know. We never release exact IQ scores to anyone, not even to the clinical patients we see here. Your results could be released to you if you had an absolute burning need and there was a qualified professional available to process the information with you. Raw testing results are not intuitively obvious.

Q. How is information valid if there is a standard error of measurement?

A. Valid within confidence intervals

Q. Why not do this testing **after** people graduate from flight screening?

A. We are also interested in having information on people who fail screening.

Q: I know we won't get individual test feedback, but will you release class results? [Class size of this particular class equaled five (5).]

A: The *n* wouldn't be large enough for a group this size. One potential outlier would skew the results. If we do publish the results, we will use a bigger *n*, probably *N* - for statistical purposes (increases significance), and to ensure that we protect confidentiality.

Post-Test

Q. Why are there redundant items within and across tests?

A. Tests are fairly interbred. We need, however, to have all items on tests answered due to standardization, etc.

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